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Russian Translation

On the Generation of Millimeter Band Radiowaves When a Bunch of Electrons Passes Through a Retarding Medium

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In the methods proposed in [1-3] of coherent sub-millimeter radiowave generation using a relativistic bunch of electrons, the effect of an artificially created electric or magnetic field (periodic or constant) on the electron bunch is used. Use of special macroscopic electromagnetic fields is not the single possible method of modulating the bunch speed. In particular, useful for pulse or periodic perturbation of the bunch is a retarding force which arises in the passage of the bunch through a medium with a modulated retarding capacity, for example, through one or a number of sheets of a dielectric, spaced at specific intervals, which is transparent to millimeter radiation.

As the bunch moves in the retarding layers of the medium, besides the coherent part of the radiation accompanying the microcollisions, there will be coherent radiation from the macroscopic retardation of the bunch as a whole. When the bunch dimensions are chosen successfully, the energy radiated coherently is:

$$\Delta\varepsilon_{coher} \approx N^2 r_o^2 E_{eff}^2 d\, n$$

where N is the number of electrons in the bunch; r_o is the classical radius of the electron; E_{eff} is the effective electric field intensity equivalent to the average retardation force within the sheet:

$$E_{eff} = \frac{1}{e}\left(\frac{d\varepsilon}{dx}\right)_{ion}$$

d is the sheet thickness, n is the number of sheets pierced by the bunch ($n = 1$

is pulse modulation, $n \gg 1$ is quasi-periodic modulation).

The radiant power for beam current intensity $I \sim 10^{-2}$ A., $d\,n \sim 0.1$ cm, $E_{eff} \sim 2$ mV/cm is:

$$W = \frac{I}{Ne}\,\Delta\varepsilon_{coher} = IN\,\frac{r_o^2}{e}\,E_{eff}^2 d\,n \approx 2\cdot 10^{-2} N \text{ erg/sec} \approx 0.1 \text{ Watt for } N \sim 5\cdot 10^{-7}$$

Despite the necessity of avoiding overheating of the retarding layers (for example, by using moving dielectric sheets or plane jets of fluid dielectric) and the necessity of attenuating bunch spreading (in the case of nonlocalized modulation of the bunch speed), in certain cases (for a given noncollimated flow of the bunch of electrons with energies $\lesssim 1$ MeV) the proposed method can simplify the construction of the submillimeter radiowave generator in order to attain high radiant power and can put in the hands of radiophysicists a simple and reliable device with easily alterable parameters instead of the complex and limited effectiveness of the experiment of the high amplitude undulator.

Use of retarding modulation facilitates the transformation to the use of plane bunches, which can be split by an additional zonal plate (similar to an optical) standing in front of or behind the velocity modulator in zones amplifying the effect of each other.

P. N. Lebedev Physics Institute June, 1954

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3. H. MOTZ, W. THON, R. WHITEHURST: Journal of Applied Physics, 24, 826, 1953